UNIVERSITAT DE BARCELONA
BUSINESS SCHOOL

MSc
Business Research

MASTER THESIS

Disentangling the relationship between R&D internationalization and corporate's innovation performance – evidence from Chinese MNEs

MSc IN BUSINESS RESEARCH

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Barcelona, 14 de Junio de 2022

Outline

Abstract

Development of the global economy makes a deeper level of interaction between the domestic and international markets in recent years. For this reason, more and more firms choose to internationalize part of their value chain in foreign countries, including research and development (R&D) activities. This paper aims to investigate the impact of R&D internationalization of Chinese MNEs on their corporate's innovation performance in terms of intensity and diversity. Using data of the Top 100 MNEs from China in 2021, I perform an Ordinary Least Square (OLS) regression to test the model. The results indicate that there is a U-shaped relationship between the intensity of R&D internationalization and firm's innovation performance and an inverted U-shaped relationship for the diversity of R&D internationalization. This paper expands the literature on innovation outcomes of R&D internationalization in the context of emerging economies and also provides guideline for those managers in MNEs to realize the threshold in the process of R&D internationalization to maximize their benefits.

Keywords: R&D internationalization, innovation performance, Chinese MNEs

JEL Classification: F23, L25, O32

1. Introduction

The internationalization of corporate research and development (R&D) activities has been increasingly widespread in recent decades (Moncada-Paterno-Castello et al., 2011). Companies are beginning to emphasize the internationalization of their R&D activities as a result of the intense global competition that requires them to seek knowledge and competencies outside of their home markets (Criscuolo,2009; Dunning & Lundan, 2009). Multinational enterprises (MNEs) can develop technological capabilities through geographically dispersed access to knowledge and increased technology diversification and complementarity through R&D internationalization, making them more competitive in the global market (Cantwell & Piscitello, 2000).

In the past two decades, a considerable number of papers focusing on various outcomes of R&D internationalization has increased. Some studies have found that R&D internationalization can

significantly improve the company's innovation performance, showing that it is a critical strategy to maintain the competitive advantage in the global market (Kafouros, Buckley, Sharp & Wang, 2008), and also can be a strategy to take advantage of low human capital costs in less developed countries (Wang, Xie, Li, & Liu, 2018). Conversely, other studies have found that foreign enterprises' liability renders MNEs performing R&D overseas less successful than those undertaking R&D in their home country (Sofka, 2006).

Main researches on R&D internationalization have been traditionally done from the perspective of MNEs from developed countries. However, in recent years there are more articles analyzing internationalization of R&D of EMNEs (Emerging Market Multinationals) specifically from China's perspective. For example, the research from Ren et al. (2015) indicates that for SMEs in China, the effect of R&D internationalization on the innovation performance is positive only when their marketing capability is high. Si et al. (2021) show that R&D internationalization is positively related to innovation performance for Chinese firms in ICT (Information and Communications Technology) industry. Also, the research of Piperopoulos et al. (2018) supports that EMNEs could employ OFDI (outward foreign direct investment) to globalize their R&D activities and improve their innovation performance… However, although there are recent literatures on R&D internationalization of Chinese MNEs, few deeply study the relationship between innovation performance and intensity (proportion of a firm's R&D activities outside its home country) and diversity (geographic distribution) of R&D internationalization activities. This paper aims to fill this gap, trying to explain R&D internationalization in these two specific dimensions to expand the research in this area and provide some insights for those managers in EMNEs to better implement the internationalization of R&D activities.

As a representative of an emerging economy, China has proposed and implemented the "going out" (zouchuqu) development strategy in 2000, boosting the international expansion of Chinese MNEs with their growing involvement in global market (Di Minin et al., 2012) and aiming to constantly chasing and surpassing industry technology leaders. Chinese MNEs, as late comers in global market, their cumulative technological level and R&D resource expenditure are somewhat inadequate. At the same time, they are facing fierce competition with industrial giants in developed countries. Therefore, it is important to study how Chinese MNEs overcome these technological constraints by internationalizing R&D activities in order to maximize the final innovation outcomes brought by this process.

To do so, this paper analyses the current situation of Chinese MNEs and tries to understand their

motivation and the benefits and costs of the process of R&D internationalization. Once contextualized the phenomenon of study we pose the following research questions: For firms from emerging economies, (1) what's the relationship between the degree of R&D internationalization and innovation performance? and, (2) what's the relationship between the geographic diversification of R&D internationalization and innovation performance?

To answer these questions, the present paper has taken 100 Chinese MNEs included in the list of "Top 100 Chinese Multinational Companies in 2021" as the sample, and OLS regression has been used to do the quantitative research. The results indicate that there is a U-shaped relationship between the intensity of R&D internationalization and innovation performance, and an inverted U-shaped relationship between the diversity of R&D internationalization and innovation performance for Chinese MNEs.

The paper will be organized as follows. In the next section, I'll discuss the literature about the R&D internationalization in general, including its motivations, benefits and costs. Also, I focus on the current status of Chinese MNEs and the hypothesis would be presented after this part. Secondly, the methodology of this paper will be presented with those variables, sample and models. Then, there will be a description and analysis of the data and results. The final section provides a discussion of my findings, examines the implication of the paper, points out the limitation and some possible future lines of research.

2. Literature review

2.1 R&D internationalization

On the one hand, in this paper R&D is defined as systematic creative work undertaken to increase the stock of knowledge (including knowledge of man, culture, and society) and the application of that knowledge to develop new applications (OECD,2012). On the other hand, the term "R&D internationalization" refers to multinational firms expanding their research and development operations outside their home nations and utilize the scientific and technology resources of several countries to conduct R&D activities across national borders.

2.1.1 Motivations for R&D Internationalization

Scholars have conducted early and fruitful researches on the motivation of R&D internationalization. As early as in 1977, Dunning proposed "The Eclectic Paradigm of International Production" which asserted that foreign direct investment of MNEs is determined by their own advantages (ownership advantage). In other words, enterprises extend their own advantages overseas to consolidate them and obtain benefits. Specifically regarding to R&D internationalization, scholars have divided the motivation of transnational R&D behaviors into two categories (di Minin et al., 2012).

The first is the market-driven type; accordingly, firms internationalize R&D activities to exploit their own advantage of knowledge and technology overseas to meet the demands of a bigger market. According to research from Kuemmerle (1999), MNEs helps the localization of the parent company's products by R&D internationalization to match the needs of the target market, hence increasing profit margins, thanks to its relatively mature technology. In this vein, Liu et al. (2010) take electrical appliance manufacturing enterprises as an example to illustrate this motivation. Since Chinese MNEs have low brand awareness in the world, the purpose of their R&D internationalization activities is to enhance firm's reputation, understand the needs of customers and develop their products for the differences in overseas markets. Moreover, the research of von Zedtwitz and Gassmann (2002) indicates that some Chinese companies have set up R&D subsidiaries in less developed regions to better meet local needs through localization of technology and products in order to develop their market into host country.

The second category is called technology-driven, which aims at acquiring technology and absorbing knowledge spillovers to enhance firm's own innovation capabilities. Because most of companies in emerging countries start late and have relatively insufficient advantages to conduct cross-border R&D activities, their motivation is primarily to obtain excellent R&D resources, fill relevant technical gaps and deficiencies, in order to enhance innovation ability (di Minin et al., 2012). Chinese MNEs need to use the technical resources of countries and regions with relatively strong R&D capabilities to enhance the scientific research capabilities of their parent companies. According to di Minin et al. (2012), the reason why ZTE (a Chinese corporation of telecommunication and information technology) can grow from a chaser to an industry leader is that the R&D subsidiary located in the birthplace of international communication technology, which makes them track and learn of industry-leading technologies.

2.1.2 Benefits and costs of R&D internationalization

The literature suggests that since the 1980s, R&D activity has rapidly become more internationally fragmented (Picci, 2010), especially in Western developed countries. R&D internationalization helps firms to obtain technical resources from all over the world and creates the chance to transform from followers into leaders (Tang et al., 2019). Customers may be a tremendous source of new ideas and product development, and having a close presence can help firms collaborate better with them. (von Hippel, 2005). Also, the development of R&D activities in international subsidiaries can increase the work efficiency of their managers and employees by fostering their working skills continuously (Williams&Lee,2016). Furthermore, organizations might profit from worldwide R&D operations through information spillover from foreign competitors and customers. To achieve that, R&D units must be placed near the source of information. (Kuemmerle, 1999). As a result of their increased engagement in internationalization of R&D operations, they will get a greater knowledge base, possible spillover effects, and improved company innovation performance. (Rahko, 2015).

Of course, there will be some additional costs in the process of implementing and controlling R&D activities outside the home country. Entering a foreign market will bring institutional disparities between a company's home base and the host nations, which might raise the cost of obtaining effective expertise due to the difficulty of developing a common language and code (Castellani, Jimenez, & Zanfei, 2013). Although R&D activities could offer the potential for economies of scale, the impact of decentralization on internationalization may hold back this goal's realization (Argyres and Silverman, 2004). Distances in terms of geography and culture make communication and learning more time-consuming and challenging. Face-to-face meetings, which are especially important in R&D departments for the transfer of tacit knowledge, are becoming less prevalent as geographic distance grows (von Zedtwitz and Gassmann, 2002). The danger of corporate intellectual property infringement and knowledge spillover may also rise as R&D activities become more internationalized which may do harm to firm’s performance (Schmiele,2013).

Therefore, there are pros and con of R&D internationalization that can affect innovation performance. By internationalizing R&D activities, MNEs could acquire richer technological resources, information spillover from foreign countries and better collaboration with their customers, which will improve the innovation performance. However, the institutional disparity, the failure in realization of economies of scale and the danger of knowledge leakage will do harm to innovation performance. So,

what's really important for MNEs is how to reduce the cost brought by internationalization and maximize the benefit of this process. MNEs should pay attention to early strategic layout in the optimal allocation of global innovation resources and develop different strategies according to different stages of internationalization.

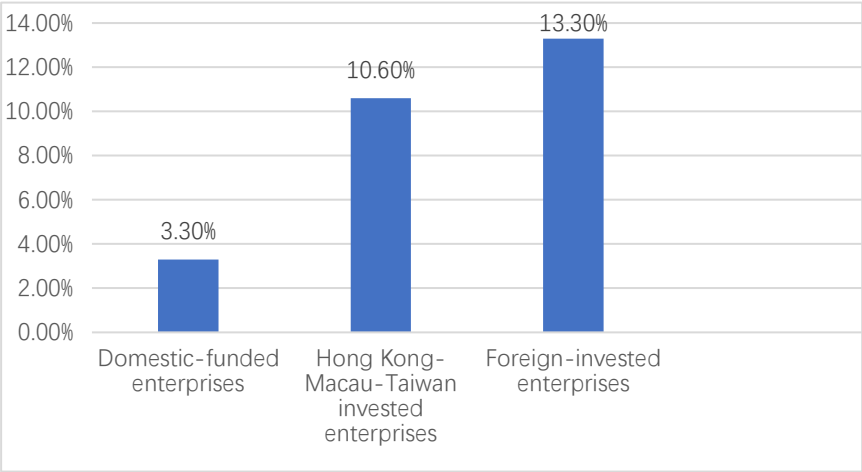
2.2 R&D internationalization of Chinese MNEs

Since China implemented the development strategy of "going out" in 2000, it has ranked among the top three in the world for 9 consecutive years in the global OFDI flow ranking until 2020. China's foreign direct investment flow was US$153.71 billion, a year-on-year increase of 12.3%, ranked No. 1 in the world for the first time in2020 (MOFCOM,2020). In terms of industry, Chinese companies' foreign mergers and acquisitions are concentrated in manufacturing and knowledge-intensive industries like information technology, and the OFDI (outward Foreign Direct Investment) structure is constantly being optimized. Chinese enterprises' overseas acquisitions are largely concentrated in countries with strong R&D capabilities, located in the developed economies such as America and Canada. To some extent, this indicates that Chinese firms are increasingly expanding their internationalization to include R&D activities, turning to overseas investment for the aim of technology acquisition, and approaching the stage of R&D internationalization.

According to the National Intellectual Property Administration's 2020 Chinese Patent Data Survey Report, the internationalization of Chinese MNEs' R&D activities will vary depending on the type and scale of the enterprise. The application of foreign patents is one of the important indicators of internationalization of R&D activities. Figure1 shows that foreign-invested enterprises have the highest proportion of foreign patent applications among three types of enterprises.

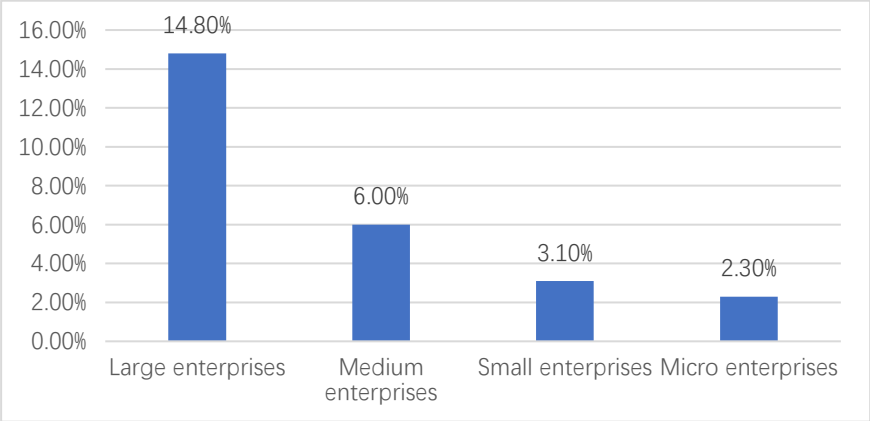
Furthermore, as shown in Figure 2, 14.8% of large firms submitted overseas patent applications. It can be seen that Chinese firm's R&D internationalization is mainly dominated by large enterprises and foreign-funded enterprises with rich internationalization experience, who usually have certain management capabilities and technical foundations, and can better support these activities.

Figure1. Patent applications (including PCT (Patent Cooperation Treaty)) submitted abroad by enterprises of different registration types (Unit: %)



Source: 2020 Chinese Patent Data Survey Report
https://www.cnipa.gov.cn/module/download/down.jsp?i_ID=158969&colID=88

Figure 2. Patent applications (including PCT (Patent Cooperation Treaty)) submitted overseas by enterprises of different scales (unit: %)



Source: 2020 Chinese Patent Data Survey Report
https://www.cnipa.gov.cn/module/download/down.jsp?i_ID=158969&colID=88

According to Child and Rodrigues (2005), Chinese MNEs use three ways of internationalization. First, they gain the technology or capabilities they require, seeking to partner with international MNEs through joint ventures, contract manufacturing or technology licensing. The second way is the use of mergers and acquisitions (M&A), since this entry mode can speed up the process of acquiring

technology and securing R&D capabilities, in addition to ensuring the supply of raw materials and resources. And the last one is the greenfield investment; for example, setting up overseas R&D subsidiaries, the expansion aims not only to improve management control and worldwide integration, but also helps to suit better the local market demands. As Fan (2011) concluded after studying the example of Huawei and ZTE Corporation, the establishment of foreign R&D centers by Chinese companies is an important step in gaining access to global knowledge and markets.

In contrast to those MNEs in developed countries, EMNEs have to face additional challenges when investing in international R&D because of the significant cultural, institutional, and technological disparities (Schaefer & Liefner, 2017). However, by performing R&D activities in foreign countries, Chinese MNEs could narrow the resource and knowledge gap as latecomers and raise their global innovation capability (Miesing et al., 2006).

2.3 Development of hypotheses

2.3.1 Degree of R&D internationalization and innovation performance

The intensity or proportion of a firm's R&D activities outside its home country can be defined as the firm's degree of R&D internationalization (Narula & Santangelo, 2009). As have been mentioned in previous sections, when the firm increases its degree of internationalization, it will incur some additional costs in controlling R&D activities. As the degree of internationalization rises, it will be more difficult to secure the strategic return from R&D activities (Athukorala & Kohpaiboon,2010). Also, the high internationalization intensity of the company's R&D activities may require duplication and administrative support of certain specialized assets (Berry,2013). More importantly, the costs derived from the institutional distance between host country and firm’s home base can be further due to the highly internationalized R&D activities. As this distance grows, the internationalization would be hindered because of the difficulty of communicating and transferring knowledge (Child & Rodrigues, 2005).

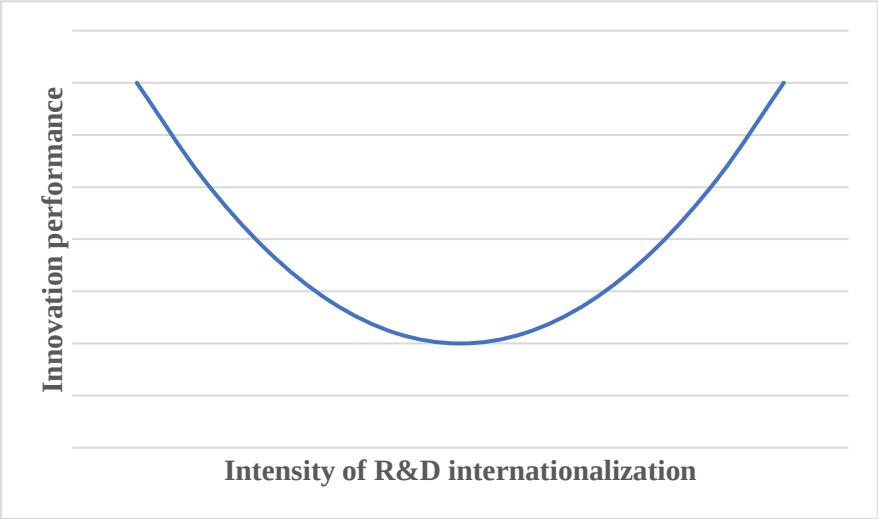
However, MNEs that present a high degree of R&D internationalization increase the stock of knowledge accumulated and the availability to maintain and enhance innovation activity (Edler, 2008).

Starting the process of locating some R & D activities in foreign subsidiaries is a good strategy to support an MNE's subsidiaries' perceived value and motivate foreign managers and staff (Williams & Lee,2016). In this vein, Iwasa and Odagiri (2004) has shown empirically on study of Japanese manufacturing firms that the higher intensity of R&D internationalization, the better the innovation performance. Moreover, based on the sample of Japanese pharmaceutical multinational corporations, Penner-Hahn and Shaver (2005) have also found that enterprises with higher levels of R&D internationalization are more likely to have higher levels of innovation output.

Based on the research and fact that the intensity of R&D internationalization has both benefits and costs, we expect that growing R&D internationalization at the beginning has a negative impact on firms in emerging market to some extent, owing to the liability of foreignness (Thomas,2006); then after a certain point, the benefits of internationalizing R&D begin to outweigh the costs. Just as Figure 3 shows below. Over all, we hypothesize:

H1: EMNEs have a U-shaped relationship between intensity of R&D internationalization and their innovation performance.

Figure 3. The U-shaped relationship between R&D internationalization intensity and innovation performance.



2.3.2 Geographic diversification of R & D internationalization and innovative performance

The geographic distribution of a firm's R&D operations, which represents the heterogeneity of the different countries in which MNEs' R&D activities are situated, is another feature of R&D internationalization that may impact a firm's innovation performance (Leiponen & Helfat, 2011).

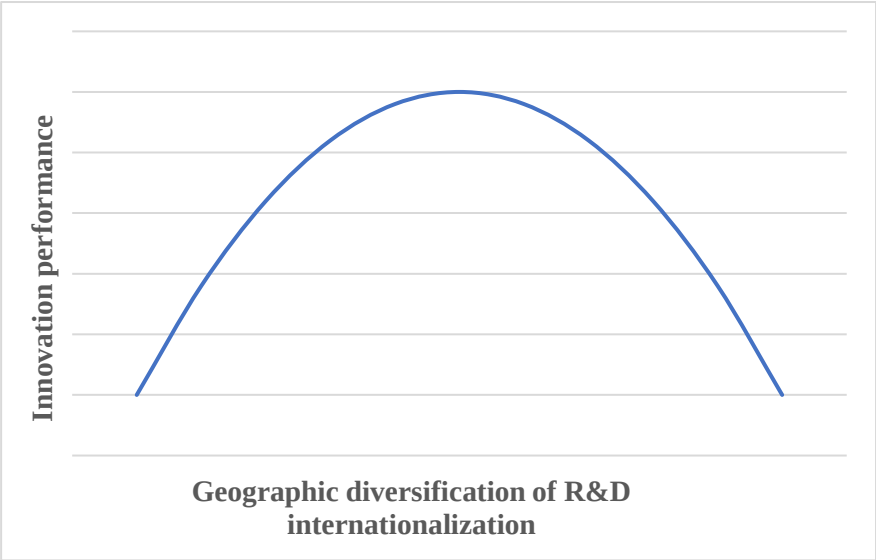
Many different location-specific advantages are readily available once MNEs begin to geographically diversify their international R&D activities. For example, the different time zones that may shorten the innovation development cycle (Carlsson, 2006), more opportunities to better appreciate the value of different external demands and trends (Cloodt et al., 2006), and the access to enhance the complementarity of their overall technological capability base by acquiring different forms of foreign technological capability knowledge (Singh, 2008) are different aspects that can explain the growth and improvement of R&D performance. Moreover, MNEs could benefit from the externality of knowledge and technology in host country by the transnational network which pushes the absorption of internationally specialized information. Spillovers like this could facilitate the knowledge sourcing of those firms and augment the innovation eventually (Kafouros et al., 2012).

Whatever, as MNE's R&D activities become more geographically diverse, the challenges grow with that. According to Kotabe et al. (2007), a highly fragmented international knowledge sourcing may increase complexity beyond acceptable levels for effective communication and coordination. With increasing geographic diversification of R&D internationalization, it may also be difficult to achieve higher levels of coordination and communication to avoid unnecessary duplication of effort, which would increase the cost of innovation (Von Zedtwitz & Gassmann, 2002).

According to Hurtado-Torres et al. (2018), EMNEs could improve their technological competence by the acquirement of knowledge and institutional advantage at the beginning of geographic diversification. However, after a certain point, the disadvantage would overcome the advantage. Just as Figure 4 shows below. Overall, we hypothesize:

H2: EMNEs have an inverted U-shaped relationship between geographical diversification of R&D internationalization and their innovation performance.

Figure 4. The inverted U-shaped relationship between geographic diversification of R & D internationalization and innovative performance.



3. Methodology

3.1 Data collection and sample

In order to test the research hypothesis, I have selected 100 Chinese MNEs included in the list of "Top 100 Chinese Multinational Companies in 2021" released by the Chinese Enterprise Federation and Chinese Enterprise Association. This ranking is made from the top 500 Chinese enterprises, based on data voluntarily declared by enterprises and with reference to the standards of Transnationality Index (TNI) made by the United Nations Conference on Trade and Development (UNCTAD). These top 100 MNEs are non-financial companies with overseas assets, revenue and employees, ranked according to the total amount of their overseas assets. China is a typical emerging economy, so these MNEs have an important active presence in foreign markets and more possibility of internationalizing R&D activities.

To build the MNEs sample dataset, I have used several sources of information. On the one hand, to collect firm's patent and financial data total assets, (i.e., total assets, financial leverage and return of assets), I have searched at "Tian yancha" and "Tong huashun" websites. (https://www.tianyancha.com/ ; https://www.10jqka.com.cn/) The first one, is known as a website of business service that mainly provides professional enterprise information and relationship mining service, and carries out the integration of full industrial and commercial data, trademark data and public litigation data. The other

one, is a professional internet financial data service provider, that includes comprehensive disclosure of firm's financial information and global financial market conditions. On the other hand, other data about foreign subsidiaries and the location of overseas R&D activity was collected one by one from the companies' official websites, corporate annual reports and some major news websites. It has taken a lot of time and effort because not every company clearly disclosures information related to R&D in their annual reports. So, in many cases it was necessary to search the information directly on the firm's official website or indirectly through other secondary sources such as digital newspapers news. Finally, as a result of the whole process to perform the empirical research of this paper, I have built a cross-sectional dataset of 100 Chinese MNEs with R&D activities located in foreign countries in 2021.

3.2 Variables and measurement

3.2.1 Dependent variable

According to Ren et al. (2015), Innovation performance (LNpatent) has been measured by the amount of patent applications of those 100 Chinese MNEs. To ensure the operability of data indicators in empirical research, I have taken the logarithm of the number of patent applications to process. As a metric of innovation performance, patents have various advantages because they include standardized data about new concepts and technical advancements (Frietsch & Grupp, 2006). Also, this measure is valid to capture innovation performance because a patent effectively grants the company property rights and increases the asset value of the company (Scherer & Ross, 1990).

3.2.2 Independent variables

R&D internationalization Intensity (RDI) has been built according to Hsu et al. (2015), dividing the number of R&D subsidiaries a company has by the total number of international subsidiaries in a particular year. This number represents the extent to which a company's R&D activities were involved in its international expansion.

For the Geographic diversification of R&D internationalization (RDD), I have calculated it using the Blau index of diversity (Collins & Blau, 1979):

$$D = 1 - \sum_{i=1}^{2} P^2 i$$

I calculated the location of R&D subsidiaries based on economic development levels, with Pi = 1 representing the proportion of R&D subsidiaries invested in developed nations and Pi = 2 representing the proportion of R&D subsidiaries invested in developing countries.

3.2.3 Control variables

I also have controlled certain factors that may impact a firm's innovation performance in addition to the primary hypotheses-testing variables. According to Ren et al. (2015), I have taken firm size (SIZE) as a control variable, which has been measured as the natural logarithm of a firm's total asset. Next control variable is the firm age (AGE), which is the number of years since the parent company was established. Financial leverage (LEVERAGE) was defined as a company's total debt divided by total assets in a given year, and it served as a good proxy for the company's financial structure (Hsu et al., 2015). Finally, I have chosen the profitability of the firm (ROA), which has been measured by the ROA, the ratio of operating profit to total assets (Hurtado-Torres et al., 2018).

Before the regression analysis is carried out in this paper, the relevant descriptive statistics are made for each variable, which is reflected in the following Table 1. The mean and standard deviation of each variable and the minimum and maximum value of each variable are obtained in the table. As we can see, the average of the logarithm of patent applications is 3.584 and the standard deviation is 2.003. The average of RDI is 0.394, which means China is still in an early stage of R&D internationalization. The average of RDD is 0.161, which shows that Chinese MNEs are relatively concentrated in setting up R&D subsidiaries overseas.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LNpatent	100	3.584	2.003	0	9.274
RDI	100	.394	.302	0	.863
RDI2	100	.277	.226	0	1
RDD	100	.161	.225	0	1
RDD2	100	.135	.12	0	.548

SIZE	100	6.69	1.724	-.775	9.801
LEV	100	.591	.175	.004	1.22
ROA	100	8.56	12.723	-34.18	87.18
AGE	100	24.78	11.639	5	71

3.3 Regression model specification

Based on the cross-sectional data of China's top 100 multinational companies in 2021, this paper conducts an empirical analysis of the above assumptions using STATA as the data analysis software for quantitative regression, and establishes the following basic econometric models: Model 1 and Model 2 includes separately R&D Internationalization Intensity and Geographic diversification of R&D internationalization.

Model 1: $Ln(Patents) = \beta_0 + \beta_1(RDI) + \beta_2(RDI)^2 + \beta_3(AGE) + \beta_4(LEV) + \beta_5(SIZE) + \beta_6(ROA) + \varepsilon$

Model 2: $Ln(Patents) = \beta_0 + \beta_1(RDD) + \beta_2(RDD)^2 + \beta_3(AGE) + \beta_4(LEV) + \beta_5(SIZE) + \beta_6(ROA) + \varepsilon$

In the model, the dependent variable, Lnpatent, is used to represent innovation performance, which is measured by the logarithm of the total number of patent applications of firms. To explain innovation performance, the regression model 1 includes the level of R&D internationalization measured by the R&D intensity (RDI) and the model 2, the R&D geographical diversification (RDD). These models also include the firm age (AGE), the financial leverage (LEV), the firm size (SIZE) and return of assets (ROA) as control variables. $\beta 0$ is the constant term and ε is the disturbance term.

4. Empirical analysis and results

Before performing the regression, it has also been tested the existence of multicollinearity problem (see Table 2). It is observed that the VIF value of each variable is from 1.03 to 1.24, so all of them are smaller than 5, indicating that there is no multicollinearity among the variables.

Table 2: Variance inflation factors (VIFs)

Variables	VIF	1/VIF
RDI	1.030	0.969
RDI2	1.240	0.806
RDD	1.060	0.946
RDD2	1.200	0.831
SIZE	1.170	0.858
LEV	1.090	0.917
ROA	1.090	0.918
AGE	1.030	0.972
Mean VIF	1.110	

Next, Table 3 shows the correlation between variables to preliminarily indicate the basic relationship among variables. From the correlation result we can obtain the preliminarily relationship among the dependent variable and independent variables. For example, both the squared term of RDI and RDD show a relatively stronger positive relationship with the logarithm of patent applications than others, from which we can pre-identify the "U" relationship among the squared term of RDI and RDD and the innovation performance.

Table 3: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) LNpatent	1.000								
(2) RDI	0.119	1.000							
(3) RDI2	0.284	-0.005	1.000						
(4) RDD	-0.068	0.023	-0.200	1.000					
(5) RDD2	-0.278	-0.111	-0.362	0.039	1.000				
(6) SIZE	0.273	0.020	0.141	-0.018	0.006	1.000			
(7) LEV	0.010	-0.049	0.076	-0.117	-0.084	0.230	1.000		
(8) ROA	0.045	0.016	-0.014	0.002	-0.089	0.243	0.023	1.000	
(9) AGE	0.068	0.099	0.015	-0.004	0.019	0.071	0.087	-0.060	1.000

Table 4 shows the results of Ordinary Least Square regressions of Model 1 and Model 2.:

Table 4: Regression results of Model 1 and 2

	Model 1		Model 2	
	Coef.	Std. err.	Coef.	Std. err.
RDI	0.719	0.638		
RDI2	2.248032**	0.857		
SIZE	.2898839**	0.119	.3522706***	0.117
LEV	-0.741	1.130	-1.091	1.130
ROA	-0.002	0.016	-0.008	0.015
AGE	0.007	0.017	0.010	0.016
RDD			-0.549	0.847
RDD2			-4.856216***	1.593
Contstant	1.015	0.996	2.438599**	1.005
R-squared	0.155		0.169	
Obs.	100.000		100.000	
AIC	418.873		417.201	
BIC	437.109		435.437	

***p < 0.01, **p < 0.05, * p < 0.1

To verify hypothesis 1, I first add the intensity of R&D internationalization (RDI) and its squared term in the model to test its effect on innovation performance. The result shows that RDI is not significant at 5% level while RDI2 is significantly positive (2.248) at 5% level, which means that there is a U-shaped relationship between the intensity of R&D internationalization and firm's innovation performance. Thus, H1 is supported.

Likewise, for hypothesis 2, the result shows that RDD is not significant at 5% level while RDD2 is significantly negative (-4.856) at 1% level, which means that there is an inverted U-shaped relationship between the diversity of R&D internationalization and firm's innovation performance. Thus, H2 is supported.

To ensure the robustness of the research results, I also conducted a white test to test the reliability of these results (see Table5). The analysis shows the existence of heteroscedasticity (P<0.05), so it is needed to run a robust regression as proposed by White (1980) to solve this problem.

Table5: Results of Robust regression

	Model 1		Model 2	
	Coef.	Std. err.	Coef.	Std. err.
RDI	0.719	0.661		
RDI2	2.248*	1.186		
SIZE	0.290**	0.138	.352***	0.121
LEV	-0.741	1.214	-1.091	1.063
ROA	-0.002	0.016	-0.008	0.017
AGE	0.007	0.022	0.010	0.020
RDD			-0.549	0.842
RDD2			-4.856***	1.805
Constant	1.015	0.978	2.439**	1.087
R-squared	0.155		0.169	
Obs.	100.000		100.000	
AIC	418.873		417.201	
BIC	437.109		435.437	

***p < 0.01, **p < 0.05, * p < 0.1

From the results, we can see that RDI is not significant at 5% level while the squared term of RDI (RDI2) is significantly positive (2.248) at 10% level, indicating the U-shaped relationship between intensity of R&D internationalization and innovation performance, which is consistent with our previous regression results. Then, the result of Model 2 shows that RDD is not significant at 5% level while the squared term of RDD (RDD2) is significantly negative (-4.856) at 1% level, indicating an inverted U-shaped relationship between diversity of R&D internationalization and innovation performance, which is also consistent with the previous result. Therefore, seems that the results of our initial regressions have great robustness.

5. Discussion and conclusions

This article analyzes empirically the influence of R&D internationalization on the innovation performance of Chinese MNEs from the perspective of enterprises, using particular R&D data from China's top 100 multinational corporations in 2021. Specifically, it analyzes Chinese MNEs' innovation performance based on the two perspectives of R&D internationalization: intensity and diversity. The paper finds two main results. First, there is a U-shaped relationship between the intensity of R&D

internationalization and innovation performance for Chinese MNEs. This means that within a certain range, with the increase of RDI, innovation performance will present a tendency of decline. Then after a certain point, the benefits outweigh its costs and the innovation performance will increase. Due to the fact that Chinese MNEs are still in an early stage of R&D internationalization, they are lack of capabilities and experiences to solve the problems confronted during the process of innovation internationalization. If companies fail to effectively protect innovation fruit, the spillover and the leakage of core innovation outcomes will reduce their innovation performance. As firms continue to learn and accumulate experience in relevant issues, the disadvantage as outsiders will be weakened, and they would obtain richer accesses to new resources, which further enhance the innovation outcomes for themselves.

Second, on the contrary, there is an inverted U-shaped relationship between the diversity of R&D internationalization and innovation performance for Chinese MNEs. In order to obtain various heterogeneous knowledge sources, those enterprises will choose to invest R&D activities in different countries, showing a great geographical dispersion. At the beginning, when the enterprise just set abroad for overseas research and development, the expansion across national borders enables them to quickly absorb technical knowledge that is more advanced than its own, and combine it with different elements from many regions to form a new knowledge frame, that will help them realize an improvement of corporate innovation performance. However, with the increasing number of international subsidiaries performing R&D activities, MNEs must have strong manpower and financial resources as a support; if they don't have these resources, a blind expansion would increase the management cost of enterprises in terms of communication and coordination. Furthermore, it would also increase the complexity of the knowledge searching and integration process in the overall multinational corporate system and makes the disadvantage of outsiders more obvious. Therefore, there will be a negative impact on the innovation performance, which supports an inverted U-shaped relationship between them.

All in all, in the academic field this paper contributes to the expansion of theoretical model to study the effects of R&D internationalization on innovation performance in these two dimensions: intensity and diversity, noticing that they have a different influence. Moreover, the empirical data consisting of MNEs from China, examines specifically the issue in a context of emerging economies. So, the findings obtained help to expand literature in this area by showing opportunities and challenges for EMNEs in the process of internationalizing their R&D activities.

There are also some practical implications of the paper. For example, managers of EMNEs have to understand the importance of specific decisions regarding the company's R&D internationalization strategy. Specifically, they could use econometric methods to find the threshold in the process of R&D internationalization, in order to stop their loss in time and maximize the profits of the whole corporation. The benefits and costs in this process would be influenced by their specific decisions. Moreover, the finding indicates that for EMNEs, R&D internationalization can be a long-term strategic choice for enhancing their innovative capabilities. This can be an inspiration for firms that always focus on domestic market, pushing them to expand their R&D business to global market to get more knowledge and technological source. By actively carrying out R&D cooperation with top enterprises in other countries, they will broaden the service scope and technical boundaries, thereby enhancing the innovation capabilities and strength of international competition.

Although this paper has important findings and implications, it is not exempt from limitations. First, this paper uses cross sectional data of Chinese MNEs instead of panel data, which makes the study limited by the number of years and couldn't indicate the trend with the change of years. Secondly, to investigate the top 100 Chinese MNEs, industry wasn't be controlled to be the same, which may lead to some bias in the results. Thirdly, I've only taken patent applications as the indicator of innovation performances, which may be not that accurate. We acknowledge that not all inventions are patented, as some companies may choose not to disclose certain information in patents for protecting the spillover (Noailly & Ryfisch, 2015). More accurate measurements could be found later. Finally, this paper only focuses on Chinese MNEs, it's a single-country analysis. Expanding the study to include more countries in emerging economy would allow for a more thorough generalization of the findings.

For lines of future research, I think it might also be meaningful to investigate the characteristics of various geographical regions and their different impact on innovation performance. This will help those MNEs that are preparing to carry out R&D internationalization strategies in different regions.

References

Argyres, N. & B. Silverman. (2004). R&D, organization structure, and the development of corporate technological knowledge. *Strategic Management Journal*, 25, 929– 958.

Athukorala, P., Kohpaiboon, A. (2010). Globalization of R&D by US-based multinational enterprises. *Research Policy* ,39, 1335-1347.

Berry, H. (2013). Too much of a good thing? Absorptive capacity, firm performance, and the moderating role of entrepreneurial orientation. *Strategic Management Journal*, 22. http://dx.doi.org/10.1002/smj

Carlsson, B. (2006). Internationalization of innovation systems: A survey of the literature. *Research Policy* ,35(1),56–67.

Castellani, D., Jimenez, A., & Zanfei, A. (2013). How remote are R & D labs? Distance factors and international innovative activities. *Journal of International Business Studies* ,44(7), 649–675.

Child, J., & Rodrigues, S. B. (2005). The Internationalization of Chinese Firms: A Case for Theoretical Extension? *Management and Organization Review*, 1(3), 381–410.

Cloodt, M., Hagedoorn, J., & Van Kranenburg, H. (2006). Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries. *Research Policy* ,35(5), 642–654.

Collins, R., & Blau, P. M. (1979). Inequality and Heterogeneity: A Primitive Theory of Social Structure. *Social Forces*, 58(2), 677.

Criscuolo, P. (2009). Inter-firm reverse technology transfer: The home country effect of R&D internationalization. *Industrial and Corporate Change*,18,869–899.

Di Minin, A., Zhang, J., & Gammeltoft, P. (2012). Chinese foreign direct investment in R&D in Europe: A new model of R&D internationalization? *European Management Journal* ,30(3), 189–203.

Dunning, J. H., & Lundan, S. M. (2009). The internationalization of corporate R&D: A review of the evidence and some policy implications for home countries. *Review of Policy Research* ,26(1–2),13–33.

Edler, J. (2008). Creative internationalization: Widening the perspectives on analysis and policy regarding international R & D activities. *Journal of Technology Transfer* ,33(4), 337–352.

Fan, P. (2011). Innovation, Globalization, and Catch-Up of Latecomers: Cases of Chinese Telecom

Firms. *Environment and Planning A: Economy and Space*, 43(4), 830–849.

Frietsch, R., & Grupp, H. (2006). There's a new man in town: The paradigm Shift in Optical Technology. *Technovation* ,26(1),13–29.

Hsu, C.-W., Lien, Y.-C., & Chen, H. (2015). R & D internationalization and innovation performance. *International Business Review* ,24(2), 187–195.

Hurtado-Torres, N. E., Aragón-Correa, J. A., & Ortiz-de-Mandojana, N. (2018). How does R&D internationalization in multinational firms affect their innovative performance? The moderating role of international collaboration in the energy industry. *International Business Review*, 27(3), 514–527.

Iwasa, T., & Odagiri, H. (2004). Overseas R&D, knowledge sourcing, and patenting: An empirical study of Japanese R&D investment in the US. *Research Policy* ,33(5), 807–828.

Kafouros, M.I., Buckley, P.J., Clegg, J. (2012). The effects of global knowledge reservoirs on the productivity of multinational enterprises: the role of international depth and breadth. *Res. Policy*, 41(5), 848–861.

Kafouros, M. I., Buckley, P. J., Sharp, J. A., & Wang, C. (2008). The role of internationalization in explaining innovation performance. *Technovation* ,28, 63– 74.

Kotabe, M., Srinivasan, S. S., & Aulakh, P. S. (2002). Multinationality and firm performance: The moderating role of marketing and R&D activities. *Journal of International Business Studies* ,33(1), 79–97.

Kuemmerle, W. (1999). Foreign direct investment in industrial research in the pharmaceutical and electronics industries – Results from a survey of multinational firms. *Research Policy* ,28, 807–828.

Leiponen, A., & Helfat, C. E. (2011). Location, decentralization, and knowledge sources for innovation. *Organization Science* ,22(3), 641–658.

Liu, J., Wang, Y., & Zheng, G. (2010). Driving forces and organisational configurations of international R&D: the case of technology-intensive Chinese multinationals. *International Journal of Technology Management*, 51(2-4), 409-426.

Miesing, P., Kriger, M. P., & Slough, N. (2006). Towards a model of effective knowledge transfer within transnationals: The case of Chinese foreign invested enterprises. *The Journal of Technology Transfer*, 32(1–2), 109–122.

MOFCOM (2020). *2020 Statistical Bulletin of China's Outward Direct Investment.* China Statistics Publishing.

Moncada-Paterno-Castello, P., M. Vivarelli & P. Voigt. (2011). Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience. *Industrial and Corporate Change* ,20, 585–603.

Narula, R., & Santangelo, G. D. (2009). Location, collocation and R & D alliances in the European ICT industry. *Research Policy* ,38(2), 393–403.

Noailly, J., & Ryfisch, D. (2015). Multinational firms and the internationalization of green R&D: A review of the evidence and policy implications. *Energy Policy*, 83, 218–228.

OECD. (2012). *Science and technology*. Accessed through https://www.oecd.org/sdd/08_Science_and_technology.pdf

Penner-Hahn, J., & Shaver, M. (2005). Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms. *Strategic Management Journal* ,26, 121–140.

Picci, L. (2010). The internationalization of inventive activity: a gravity model using patent data. *Research Policy* ,39, 1070–1081.

Piperopoulos, P., Wu, J., & Wang, C. (2018). Outward FDI, location choices and innovation performance of emerging market enterprises. *Research Policy*, 47(1), 232–240.

Rahko, J. (2015). Internationalization of corporate R&D activities and innovation performance. *Industrial and Corporate Change* ,25(6), 1019-1038.

Ren, S., Eisingerich, A. B., & Tsai, H. T. (2015). How do marketing, research and development capabilities, and degree of internationalization synergistically affect the innovation performance of small and medium-sized enterprises (SMEs)? A panel data study of Chinese SMEs. *International Business Review* ,24(4), 642–651.

Schaefer, K. J., & Liefner, I. (2017). Offshore versus domestic: Can EM MNCs reach higher R&D quality abroad? *Scientometrics*, 113(3), 1349–1370.

Scherer, F., & Ross, D. (1990). Industrial market structure and economic performance. *Boston, MA: Houghton Mifflin.*

Schmiele, A. (2013). Intellectual property infringements due to R&D abroad? A comparative analysis between firms with international and domestic innovation activities. *Research Policy* ,42(8), 1482–

1495.

Si, Y., Zhang, Y., & Teng, T. (2021). R&D internationalization and innovation performance of Chinese enterprises: The mediating role of returnees and foreign professionals. *Growth and Change*, 52(4), 2194–2212.

Singh, J. (2008). Distributed R&D, cross-regional knowledge integration and quality of innovative output. *Research Policy* ,37(1), 77-96.

Sofka, W. (2006). Innovation Activities Abroad and the Effects of Liability of Foreignness: Where it Hurts. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.901212

Tang, C., Tang, Y. and Su, S. (2019). R&D internationalization, product diversification and international performance for emerging market enterprises: an empirical study on Chinese enterprises. *European Management Journal* ,37(4), 529-539.

Thomas, D. E. (2006). International diversification and firm performance in Mexican firms: A curvilinear relationship? *Journal of Business Research* ,59, 501–507.

Von Hippel, E. (2005). Democratizing innovation: the evolving phenomenon of user innovation. *Journal für Betriebswirtschaft*,55(1), 63–78.

Von Zedtwitz, M., & Gassmann, O. (2002). Market versus technology drive in R&D internationalization: four different patterns of managing research and development. *Research Policy* ,31(4), 569–588.

Wang, Y., Xie, W., Li, J. & Liu, C. (2018). What factors determine the subsidiary mode of overseas R&D by developing-country MNEs? Empirical evidence from Chinese subsidiaries abroad. *R&D Management* ,48(2), 253-265.

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica*, 48(4), 817.

Williams, C., & Lee, S. H. (2016). Knowledge flows in the emerging market MNC: The role of subsidiary HRM practices in Korean MNCs. *International Business Review* ,25(1), 233–243.